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EP-A-0 060 033
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US-A-4 292 512

ELECTRONICS LETTERS, vol. 19, no. 8, 14th April 1983, pages 295-297, London, GB; H. KUWAHARA et al.: "Tuning characteristics of optical amplification in 1.5 mum InGaAsP/InP lasers"

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Description

The present invention relates to the amplification of optical signals.

The amplification of optical signals is of especial importance in optical communications. The radiation used in optical communications is not necessarily in the visible region, and the words "optical" and 'light" when used in this specification are not to be interpreted as implying any such limitations. Indeed, of silica optical fibres are used as the transmission medium, infra-red radiation is of especial usefulness because the loss mirima occur in such fibres at 1.3 μm and 1.55 μm approximately.

A semiconductor laser comprises in general an "active layer" of low band gap material with higher band gap "confinement" layers to either side and a p-n junction in the vicinity of the active layer. When current is passed from p- to n-type material, electrons and holes combine in the active layer to generate light. The threshold current at which the onset of "lasing" occurs depends on the degree of feedback into the structure, e.g. by reflections from its end faces, on the (current dependent) gain through stimulated emission as photons pass along the active layer, and on other factors. At lower currents, the laser functions as a light emitting diode or as a superluminescent emitter. A laser in which the feedback is provided by reflections at end facets is known as a Fabry-Perot laser.

It is known that a semiconductor laser structure can be used as an optical amplifier cf. e.g. EP—A—0 060 033. Thus, it is known that if a laser structure is chosen having a wavelength of maximum gain close to the wavelength of the optical signal to be amplified and this signal is coupled into its active layer then it can be amplified if a driving current of less than the threshold value is passed through the structure from p- to n-type material. The phrase "laser structure" is used here and elsewhere in this specification to indicate the similarity of the amplifier structure to that of a laser without necessarily implying that lasing actually occurs in use.

We have given attention to the characteristic of such amplifiers that the amplifier gain for a given driving current is substantially constant from zero input power over a range of lower powers and then decreases to zero and then becomes negative (i.e. net absorption occurs) with higher powers. This is at least partly because the device saturates as the proportion of the available holes and electrons consumed increases. Increasing the driving current can be used to increase the supply of holes and electrons and therefore the gain; however, the extent to which this can be done is limited, because around the lasing threshold of the device injection-locked lasing occurs whereafter the dependence or the power input of the power output at the single emission wavelength is slight, i.e. useful amplification does not occur.

An object of the present invention is to provide means for amplifying higher input powers.

The present invention in its first aspect is based on our surprising discovery that the effects of saturation are less marked on the long-wavelength side of the wavelength of maximum gain as measured for lower powers.

In its first aspect the present invention provides a method of amplifying an optical signal which comprises coupling the optical signal to be amplified into the active layer of a semiconductor laser structure through which a driving current is passed, the amplified signal being emitted from the active layer, in which method the wavelength of the gain maximum at that driving current for the low power limit of optical power input λ_{max}, the longer of the two wavelengths of zero gain at the driving current for the low power limit of optical power input λ_{upper}, and the wavelength of the optical signal to be amplified λ are related by the relationship

$$\lambda_{upper}>\lambda>\lambda_{max}.$$

In its first aspect the present invention further provides an amplification assembly for amplifying an optical signal which comprises an optical signal source, a semiconductor laser structure, means for coupling the optical signal to be amplified into the active layer of the semiconductor laser structure, and means for passing a driving current through the semiconductor laser structure, the amplified signal being emitted from the active layer in use, wherein the wavelength of the gain maximum of the semiconductor laser structure at that driving current for the low power limit of optical power input λ_{max}, the longer of the two wavelengths of zero gain at the driving current λ_{upper}, and the wavelength of the optical signal to be amplified λ are related by the relationship

$$\lambda_{upper}>\lambda>\lambda_{max}.$$

Preferably, $(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})$ is at least 0.1, especially at least 0.2.

In a second aspect, our invention is based on our appreciation that if the input wavelength is sufficiently remote from the wavelength of the laser gain maximum to avoid injection-locking, whether on the high side or the low side, useful amplification of the input signal can be obtained with currents in excess of the threshold current.

In its second aspect, therefore, the present invention provides a method of amplifying an optical signal which comprises coupling the signal to be amplified into the active layer of a semiconductor laser structure and applying a driving current to the laser structure such that lasing occurs, the wavelength of the signal to be amplified being such that injection locking is avoided and the amplified signal is emitted from the active layer.

In its second aspect, the present invention further provides an amplification assembly for amplifying an optical signal which comprises an optical signal source, a semiconductor laser structure, means for coupling the optical signal to be amplified into the active layer of the semiconductor laser structure, and means for passing a driving current through the semiconductor laser structure such that lasing occurs, the wavelength of the signal to be amplified being such that injection locking is avoided and the amplified signal being emitted from the active layer.

In a third aspect, the present invention is based on our appreciation that the output of a laser structure under use as an optical amplifier is diminished over its entire emission range (not merely at the wavelength of the input signal) by the saturation referred to above and that this diminution offers a means of controlling the current so as to raise up the amplifier gain at higher input powers.

In this third aspect, therefore, the present invention provides a method of amplifying an optical signal which comprises coupling the signal to be amplified into the active layer of a semiconductor laser structure through which a driving current is passed, which layer emits the amplified signal, and monitoring the light emission from the active layer at a wavelength or over a wavelength range distinct from that of the amplified signal, and controlling the driving current to the laser structure so as at least partly to compensate for the decrease in the monitored output with increasing optical input.

In its third aspect, the present invention further provides an amplification assembly for amplifying an optical signal which comprises an optical signal source, a semiconductor laser structure, means for coupling the optical signal to be amplified into the active layer of the semiconductor laser structure, and means for passing a driving current through the semiconductor laser structure, the amplified signal being emitted from the active layer in use, wherein means is provided to monitor the output of the semiconductor laser structure at a wavelength or over a wavelength range distinct from that of the amplified signal, and a feedback control loop is provided which acts to control the driving current so as at least partly to compensate for the decrease in the monitored output with increased optical input power.

The invention can be employed independently in each of its three aspects, or in all three simultaneously, or in any of the three possible combinations of two aspects. In its first and third aspects, the invention can even be applied to a laser structure with so little feedback that it cannot be made to lase at any practical current (e.g. a travelling wave amplifier).

The invention will now be described by way of example only, with respect to the accompanying Figures 1 to 4 in which:—

Figure 1 shows the photon distribution along the cavity of a semiconductor laser amplifier;

Figure 2 shows the gain characteristics at different input powers of a particular semiconductor laser amplifier as calculated by means of a computer model (only selected results being shown);

Figure 3 shows (schematically, smoothed, and generalised) the results of calculations such as those selected for inclusion in Figure 2; and

Figure 4 shows, schematically and not to scale, a semiconductor laser amplification assembly which is an embodiment of the present invention in all three aspects.

Figure 1 shows how in a typical semiconductor laser amplifier the signal intensity S varies with length along the cavity of the amplifier. The signal intensity S comprises two components 21, 22 representing the forward and reflected waves travelling in opposed directions along the amplifier. The variation in signal intensity S along the length 1 of the amplifier leads to consequent variation in carrier density and gain.

We have constructed an analytical model of the laser amplifier in which the total axial photon distribution 23 is averaged over the cavity length and used to self-consistently determine a uniform carrier density. We have incorporated the refinement of a spectrally dependent gain function (the peak of which shifts with the carrier density) and the effect of carrier density on the refractive index within the cavity.

Figure 2 shows results for the gain characteristics obtained by use of this model for a Fabry-Perot laser amplifier operable near the 1.55 μm loss minimum of silica fibres in which the reflectivity of each end facet is taken to be 0.01. The current density is taken to be 0.97 times the threshold current density. The mode spacing of the laser is taken as 1 nm. The detailed results of calculations for various input powers are shown only for selected wavelengths so as to avoid congestion. The dotted lines which connect the results shown represent the general trend of the gain characteristics between these results without including detail.

It will be seen that the gain characteristics, as well as depending on wavelength and input power, show Fabry-Perot resonances. At the lowest input power the trend in the characteristics follows the trend of the material gain spectrum with the largest values of the amplification occurring at the gain peak at 1.5525 μm. With increasing input power the carrier density decreases. This reduces the amplification overall and shifts the gain peak to longer wavelengths as well as modifying the carrier-dependent refractive index.

It can be seen that the gain peak shifts according to the following Table:

TABLE 1

Input power/W	Gain peak input wavelength/μm
10^{-10}	1.5525
10^{-6}	1.5572
10^{-5}	1.5620
2×10^{-5}	1.5650
5×10^{-5}	1.5675

Hence when the input power is increased from 10^{-10}W to 10^{-6}W, the gain peak has already shifted to a longer wavelength; 1.5572 μm. The reduction in gain (13.7 dB to 13.0 dB) seen at the wavelength of maximum gain at low power 1.5525 μm, when the input power is increased to 10^{-6}W, can therefore be at least partially offset by operation at up to at least 1.5572 μm.

Referring still to Figure 2, as the input power is further increased, increasingly significant reductions in overall amplification are seen. At the same time the gain peak is shifted to increasingly longer wavelengths. The result is that increasing benefit is available, in offsetting the overall reduction in amplification by operating at longer wavelengths, as the input power is increased from 10^{-10}W to 10^{-6}W, 10^{-5}W and through the values shown to 5×10^{-5}W. It has further been observed, though not shown in Figure 2, that particularly significant benefit can be had at input powers of the order of 1 mW, for instance at input powers of 0.5 mW to 5 mW inclusive.

In Figure 3 the amplifier gain as a function of input power for a given current is shown for three different wavelengths, B near to the wavelength of maximum gain, A somewhere on the low wavelength side but within the positive part of the gain curve, and C on the long-wavelength side but likewise within the positive part of the gain curve, C showing a gain at lower power similar to that of curve A. The effect of Fabry-Perot resonances has been smoothed out. It will be seen from the part of the Figure where curve C lies highest why, if one wishes to amplify a higher input power at a particular wavelength, one can achieve best results (in accordance with the invention in its first aspect) by using a laser amplifier of which the maximum gain *at low power* is at a shorter wavelength than the signal to be amplified.

Referring again to Figure 2, it can be seen that there is a further benefit to be gained from operating at an input wavelength which is greater than the wavelength of maximum gain at low powers. The variation in gain due to increasing input powers for the wavelength of maximum gain at low powers, and for two wavelengths selected to be longer and shorter respectively, are shown in the following Table:

TABLE 2

Input power/W	Gain/dB at 1.5400 μm	Gain/dB at 1.5525 μm	Gain/dB at 1.5700 μm
10^{-10}	13.4	13.7	12.7
10^{-6}	12.1	13.0	12.4
10^{-5}	10.4	11.6	11.5
2×10^{-5}	9.0	10.5	10.8
5×10^{-5}	7.0	8.6	9.3

The further benefit referred to above is that of reduced sensitivity to increases over a range of input power. It can be seen that the reduction in gain at 1.5525 μm over the range of input powers shown is just over 37% whereas the reduction in gain at 1.5700 μm is slightly less than 27%. This reduced sensitivity to increases in input power gives the amplifier the desirable feature of having a more linear gain characteristic for increasing signal input powers. In contrast, the equivalent reduction in gain at 1.5400 μm is more than 47%.

We refer now to Figure 4.

In Figure 4, 1 represents an optical fibre carrying an input signal of wavelength 1580 nm (1.58 μm) from an optical signal source (not shown). This is coupled from the fibre end into activer layer 3 of a Fabry-Perot laser structure 2. This structure is one having a maximum gain at the low power limit of optical power input at a wavelength of 1550 nm (1.55 μm), the positive part of the gain spectrum at the low power limit of optical power input extending to 1600 nm (1.60 μm) on the long wavelength side and having an approximately similar extent to the low wavelength side. Current of above the threshold level is passed between electrodes 4 and 5 and lasing occurs in various Fabry-Perot modes distributed over the gain spectrum.

Amplification occurs at the wavelength 1580 nm of the input signal. Light emerges from 3 and is fed via lens 6 into interference filter 7. The interference filter reflects a band of radiation near to 1550 nm but not significantly the radiation at 1580 nm to lens 8 and optical detector 9. The signal including the amplified 1580 nm signal continues to lens 10 and the output optical fibre 11. $(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})$ as defined above is 0.6.

In accordance with the invention in its first aspect, the gain for high input powers from fibre 1 is higher than would have been the case had the wavelength of maximum gain of laser 2 been at 1.58 μm for the low power limit. In accordance with the invention in its second aspect, the difference between λ and λ_{max} is such that amplification occurs even for currents of above threshold, and this higher permitted current makes also for high gain. (This latter effect would be present even had the input radiation been at (say) 1.52 μm, i.e. had the first aspect of the invention not been exploited).

In the Figure, a further although independent benefit is afforded, in accordance with the present invention in its third aspect, by the use of a feedback control loop. The loop comprises the filter 7, the lens 8, the detector 9 and the control circuit 12 which receives the output signal of the detector 9. The control circuit 12 is designed to adjust the current passed between electrodes 4 and 5 to maintain a constant output from detector 9, and thereby constant amplifier gain. This circuitry would, it should be mentioned, be of value even in operation with currents below lasing threshold.

For optimum performance in the device described, the end facets will normally be anti-reflection coated, e.g. to achieve reflectivities of 0.01.

Semiconductor laser structures other than that described above may be employed. However, their characteristics, such as the input power at which significant benefits may be gained by application of the present invention, will vary from those described above.

One use of the device shown, and indeed generally of methods and amplification assemblies in accordance with the present invention, is in optical communications systems where the light from the laser source is passed through lossy components such as modulators or optical isolators before being coupled into the optical fibre of the communications link. Such arrangements are of especial significance for coherent optical systems. By using the device shown, the signal emerging from these lossy components can be amplified to make up for the losses. The input powers desired in such cases are in general high ones in the context of this specification, and therefore ones where the present invention affords advantages. Gains of about 10 dB are achievable even for input powers of 5 mW. Power on launch into the communications link is of course of the greatest importance in determining repeater spacings.

In such an application it is possible to use as the source laser and the amplifying laser devices that are practically identical except that the latter is anti-reflection coated. The source laser will lase at relatively low currents with a wavelength longer than that of the amplifier laser when made to lase with the relatively high currents that are necessary, and longer than the wavelength of maximum gain at low powers of the amplifier laser. In this way one can with relative ease secure the benefits in accordance with the present invention in its first aspect.

The methods and amplification assemblies in accordance with the present invention may also be used in optical pre-amplifiers, for instance before a detector at the receiving end of an optical signalling arrangement.

Claims

1. A method of amplifying an optical signal which comprises coupling the optical signal to be amplified into the active layer of a semiconductor laser structure through which a driving current is passed, the amplified signal being emitted from the active layer, in which method the wavelength of the gain maximum at that driving current for the low power limit of optical power input λ_{max}, the longer of the two wavelengths of zero gain at the driving current for the low power limit of optical power input λ_{upper}, and the wavelength of the optical signal to be amplified λ are related by the relationship

$$\lambda_{upper}>\lambda>\lambda_{max}.$$

2. A method according to claim 1, wherein

$$(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})\geq 0.1.$$

3. A method according to claim 1, wherein

$$(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})\geq 0.2.$$

4. A method according to any preceding claim wherein λ_{max} is in the range from 1.2 to 1.7 μm.

5. A method according to any preceding claim wherein the driving current is such that lasing does not occur.

6. A method according to any of claims 1 to 4, wherein the driving current is such that lasing occurs and the wavelength of the optical signal to be amplified is such that injection locking of the laser does not occur.

7. A method of amplifying an optical signal which comprises coupling the signal to be amplified into the active layer of a semiconductor laser structure and applying a driving current to the laser structure such that lasing occurs, the wavelength of the signal to be amplified being such that injection locking is avoided and the amplified signal is emitted from the active layer.

8. A method according to any one of claims 1 to 7 wherein the output of the semiconductor laser structure is monitored at a wavelength or over a wavelength range distinct from that of the amplified signal and the driving current is controlled so as at least partly to compensate for the decrease in the monitored output with increased optical input.

9. A method of amplifying an optical signal which comprises coupling the signal to be amplified into the active layer of a semiconductor laser structure through which a driving current is passed, which layer emits the amplified signal, and monitoring the light emission from the active layer at a wavelength or over a wavelength range distinct from that of the amplified signal, and controlling the driving current to the laser structure so as at least partly to compensate for the decrease in the monitored output with increasing optical input.

10. A method according to any preceding claim, wherein the signal to be amplified has a power which lies in the range from 1 μW to 5 mW inclusive.

11. A method according to any preceding claim, wherein the signal to be amplified has a power which lies in the range from 10 μW to 5 mW inclusive.

12. An amplification assembly for amplifying an optical signal which comprises an optical signal source, a semiconductor laser structure, means for coupling the optical signal to be amplified into the active layer of the semiconductor laser structure, and means for passing a driving current through the semiconductor laser structure, the amplified signal being emitted from the active layer in use, wherein the wavelength of the gain maximum of the semiconductor laser structure at that driving current for the low power limit of optical power input λ_{max}, the longer of the two wavelengths of zero gain at the driving current for the low power limit of optical power input λ_{upper}, and the wavelength of the optical signal to be amplified λ are related by the relationship

$$\lambda_{upper}>\lambda>\lambda_{max}.$$

13. An assembly according to claim 12, wherein

$$(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})\geq 0.1.$$

14. An assembly according to claim 12, wherein

$$(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})\geq 0.2.$$

15. An assembly according to any of claims 12 to 14 wherein λ_{max} is in the range from 1.2 to 1.7 μm.

16. An assembly according to any of claims 12 to 15 wherein the driving current is such that lasing does not occur.

17. An assembly according to any of claims 12 to 15, wherein the driving current is such that lasing occurs and the wavelength of the optical signal to be amplified is such that injection locking of the laser does not occur.

18. An amplification assembly for amplifying an optical signal which comprises an optical signal source, a semiconductor laser structure, means for coupling the optical signal to be amplified into the active layer of the semiconductor laser structure, and means for passing a driving current through the semiconductor laser structure such that lasing occurs, the wavelength of the signal to be amplified being such that injection locking is avoided and the amplified signal being emitted from the active layer.

19. An assembly according to any one of claims 12 to 18 wherein means is provided to monitor the output of the semiconductor laser structure at a wavelength or over a wavelength range distinct from that of the amplified signal and a feedback control loop is provided which acts to control the driving current so as at least partly to compensate for the decrease in the monitored output with increased optical input power.

20. An amplification assembly for amplifying an optical signal which comprises an optical signal source, a semiconductor laser structure, means for coupling the optical signal to be amplified into the active layer of the semiconductor laser structure, and means for passing a driving current through the semiconductor laser structure, the amplified signal being emitted from the active layer in use, wherein means is provided to monitor the output of the semiconductor laser structure at a wavelength or over a wavelength range distinct from that of the amplified signal and a feedback control loop is provided which acts to control the driving current so as at least partly to compensate for the decrease in the monitored output with increased optical input power.

21. An assembly according to any one of claims 12 to 20, wherein the signal to be amplified has a power which lies in the range from 1 µW to 5 mW inclusive.

22. An assembly according to any one of claims 12 to 20, wherein the signal to be amplified has a power which lies in the range from 10 µW to 5 mW.

23. An assembly according to any one of claims 12 to 20, wherein the signal to be amplified has a power which lies in the range from 0.5 mW to 5 mW inclusive.

24. An assembly according to any one of claims 12 to 23, wherein the semiconductor laser structure is of a Fabry-Perot type.

Patentansprüche

1. Ein Verfahren zum Verstärken eines optischen Signals, das aufweist Einkoppeln des zu verstärkenden optischen Signals in die aktive Schicht einer Halbleiterlaserstruktur, durch die ein Treiberstrom fließt, wobei das verstärkte Signal von der aktiven Schicht emittiert wird und wobei in dem Verfahren die Wellenlänge λ_{max} des Verstärkungsmaximums bei diesem Treiberstrom für die untere Leistungsgrenze der optischen Eingangsleistung, die längere λ_{upper} der zwei Wellenlängen bei Nullverstärkung bei dem Treiberstrom für die untere Leistungsgrenze der optischen Eingangsleistung und die Wellenlänge λ des zu verstärkenden optischen Signals verknüpft sind durch folgende Beziehung:

$$\lambda_{upper}>\lambda>\lambda_{max}.$$

2. Verfahren nach Anspruch 1, gekennzeichnet durch

$$(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})\geqq 0{,}1.$$

3. Verfahren nach Anspruch 1, gekennzeichnet durch

$$(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})\geqq 0{,}2.$$

4. Verfahren nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß λ_{max} im Bereich von 1,2 bis 1,7 µm ist.

5. Verfahren nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß der Treiberstrom so ist, daß Lasern nicht auftritt.

6. Verfahren nach einem der Ansprüche 1 bis 4, dadurch gekennzeichnet, daß der Treiberstrom so ist, daß Lasern auftritt und daß die Wellenlänge des zu verstärkenden, optischen Signals so ist, daß ein Injektionssperren des Lasers nicht auftritt.

7. Verfahren zum Verstärken eines optischen Signals, das aufweist Einkoppeln des zu verstärkenden Signals in die aktive Schicht einer Halbleiterlaserstruktur und Anlegen eines Treiberstroms an die Laserstruktur so, daß Lasern auftritt, wobei die Wellenlänge des zu verstärkenden Signals so ist, daß Injektionssperren vermieden wird und daß das verstärkte Signal von der aktiven Schicht emittiert wird.

8. Verfahren nach einem der Ansprüche 1 bis 7, dadurch gekennzeichnet, daß der Ausgang der Halbleiterlaserstruktur bei einer Wellenlänge oder über einen Wellenlängenbereich überwacht wird, der sich von dem des verstärkten Signals unterscheidet, und daß der Treiberstrom so gesteuert wird, daß zumindest teilweise das Abfallen des überwachten Ausgangsmit erhöhtem optischen Eingang kompensiert wird.

9. Verfahren zum Verstärken eines optischen Signals, das aufweist Einkoppeln des zu verstärkenden Signals in die aktive Schicht einer Halbleiterlaserstruktur, durch die ein Treiberstrom fließt, wobei die Schicht das verstärkte Signal emittiert, und Überwachen der Lichtemission von der aktiven Schicht bei einer Wellenlänge oder über einen Wellenlängenbereich, der verschieden von dem des verstärkten Signals ist, und Steuern des Treiberstroms für die Laserstruktur so, daß zumindest teilweise eine Abnahme in dem überwachten Ausgang mit ansteigendem optischen Eingang kompensiert wird.

10. Verfahren nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß das zu verstärkende Signal eine Leistung hat, die im Bereich von 1 µW bis 5 mW einschließlich liegt.

11. Verfahren nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß das zu verstärkende Signal eine Leistung hat, die in dem Bereich von 10 µW bis 5 mW inklusive liegt.

12. Verstärkungsanordnung zum Verstärken eines optischen Signals, die aufweist eine optische Signalquelle, eine Halbleiterlaserstruktur, eine Einrichtung zum Einkoppeln des zu verstärkenden, optischen Signals in die aktive Schicht der Halbleiterlaserstruktur und eine Einrichtung zum Durchfließen des Treiberstroms durch die Halbleiterlaserstruktur, wobei das verstärkte Signal von der eingesetzten aktiven Schicht emittiert wird und wobei die Wellenlänge λ_{max} des Verstärkungsmaximums der Halbleiterlaserstruktur bei diesem Treiberstrom für die untere Leistungsgrenze der optischen Eingangsleistung, die längere λ_{upper} der zwei Wellenlängen bei Nullverstärkung bei dem Treiberstrom für die untere Leistungsgrenze der optischen Eingangsleistung und die Wellenlänge λ des zu verstärkenden optischen Signals verknüpft sind durch die Beziehung

$$\lambda_{upper}>\lambda>\lambda_{max}.$$

13. Anordnung nach Anspruch 12, gekennzeichnet durch

$$(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})\geqq 0,1.$$

14. Anordnung nach Anspruch 12, gekennzeichnet durch

$$(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})\geqq 0,2.$$

15. Anordnung nach einem der Ansprüche 12 bis 14, dadurch gekennzeichnet, daß λ_{max} im Bereich von 1,2 bis 1,7 µm liegt.

16. Anordnung nach einem der Ansprüche 12 bis 15, dadurch gekennzeichnet, daß der Treiberstrom so ist, daß Lasern nicht auftritt.

17. Anordnung nach einem der Ansprüche 12 bis 15, dadurch gekennzeichnet, daß der Treiberstrom so ist, daß Lasern auftritt und daß die Wellenlänge des zu verstärkenden, optischen Signals so ist, daß Injektionssperren des Lasers nicht auftritt.

18. Verstärkungsanordnung zum Verstärken eines optischen Signals, die aufweist eine optische Signalquelle, eine Halbleiterlaserstruktur, eine Einrichtung zum Einkoppeln des optischen, zu verstärkenden Signals in die aktive Schicht der Halbleiterlaserstruktur und eine Einrichtung zum Durchfließen eines Treiberstroms durch die Halbleiterlaserstruktur so, daß Lasern auftritt, wobei die Wellenlänge des zu verstärkenden Signals so ist, daß Injektionssperren vermieden wird und daß das verstärkte Signal von der aktiven Schicht emittiert wird.

19. Anordnung nach einem der Ansprüche 12 bis 18, dadurch gekennzeichnet, daß eine Einrichtung vorgesehen ist, um den Ausgang der Halbleiterlaserstruktur bei einer Wellenlänge oder über einen Wellenlängenbereich zu überwachen, der unterschiedlich zu dem des verstärkten Signals ist und eine Rückkopplungssteuerschleife ist vorgesehen, die wirkt, um den Treiberstrom so zu kontrollieren, daß zumindest teilweise eine Abnahme des überwachten Ausgangs mit einer Zunahme der optischen Eingangsleistung kompensiert wird.

20. Verstärkungsanordnung zum Verstärken eines optischen Signals, die aufweist eine optische Signalquelle, eine Halbleiterlaserstruktur, eine Einrichtung zum Einkoppeln des zu verstärkenden, optischen Signals in die aktive Schicht der Halbleiterlaserstruktur, und eine Einrichtung zum Durchfließen eines Treiberstroms durch die Halbleiterlaserstruktur, wobei das verstärkte Signal von der eingesetzten, aktiven Schicht emittiert wird und wobei eine Einrichtung zum Überwachen des Ausgangs der Halbleiterlaserstruktur bei einer Wellenlänge oder über einen Wellenlängenbereich vorgesehen ist, der sich von dem des verstärkten Signals unterscheidet, und eine Rückkopplungssteuerschleife vorgesehen ist, die wirkt, um den Treiberstrom so zu steuern, daß zumindest teilweise eine Abnahme des überwachten Ausgangs mit einer Zunahme der optischen Eingangsleistung kompensiert wird.

21. Anordnung nach einem der Ansprüche 12 bis 20, dadurch gekennzeichnet, daß das zu verstärkende Signal eine Leistung hat, die im Bereich von 1 µW bis 5 mW liegt.

22. Anordnung nach einem der Ansprüche 12 bis 20, dadurch gekennzeichnet, daß das zu verstärkende Signal eine Leistung hat, die im Bereich von 10 µW bis 5 mW liegt.

23. Anordnung nach einem der Ansprüche 12 bis 20, dadurch gekennzeichnet, daß das zu verstärkende Signal eine Leistung hat, die im Bereich von 0,5 mW bis 5 mW einschließlich liegt.

24. Anordnung nach einem der Ansprüche 12 bis 23, dadurch gekennzeichnet, daß die Halbleiterlaserstruktur vom Fabry-Perot Typ ist.

Revendications

1. Un procédé d'amplification d'un signal optique, qui consiste à appliquer le signal optique à amplifier à la couche active d'une structure de laser semiconducteur au travers de laquelle on fait passer un courant d'excitation, le signal amplifié étant émis à partir de la couche active, procédé dans lequel la longueur d'onde du gain maximal correspondant à ce courant d'excitation pour la limite inférieure de la puissance optique d'entrée λ_{max}, la plus grande des deux longueurs d'ondes de gain nul correspondant au courant d'excitation pour la limite inférieure de la puissance optique d'entrée λ_{upper}, et la longueur d'onde du signal optique à amplifier λ sont liées par la relation suivante:

$$\lambda_{upper}>\lambda>\lambda_{max}.$$

2. Un procédé selon la revendication 1, dans lequel:

$$(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})\geqslant 0,1.$$

3. Un procédé selon la revendication 1, dans lequel:

$$(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})\geqslant 0,2.$$

4. Un procédé selon une quelconque des revendications précédentes, dans lequel: λ_{max} rentre dans la gamme comprise entre 1,2 et 1,7 µm.

5. Un procédé selon une quelconque des revendications précédentes, dans lequel le courant d'excitation est tel qu'il ne se produit pas d'effet laser.

6. Un procédé selon une quelconque des revendications 1 à 4, dans lequel le courant d'excitation est tel qu'il se produit un effet laser et que la longueur d'onde du signal optique à amplifier est telle qu'il ne se produit pas de blocage d'injection du laser.

7. Un procédé d'amplification d'un signal optique qui consiste à appliquer le signal à amplifier à la couche active d'une structure de laser semiconducteur et à appliquer un courant d'excitation à la structure de laser de telle sorte qu'il se produise un effet laser, la longueur d'onde du signal à amplifier étant telle qu'un blocage d'injection soit évité et que le signal amplifié soit émis à partir de la couche active.

8. Un procédé selon une quelconque des revendications 1 à 7, dans lequel la puissance de sortie de la structure de laser semiconducteur est contrôlée à une longueur d'onde ou dans une gamme de longueurs d'ondes distincte de celle du signal amplifié et le courant d'excitation est commandé de façon à compenser au moins partiellement la diminution de la puissance de sortie contrôlée lors d'une augmentation de la puissance optique d'entrée.

9. Un procédé d'amplification d'un signal optique, qui consiste à appliquer le signal à amplifier à la couche active d'une structure de laser semiconducteur dans laquelle on fait passer un courant d'excitation, ladite couche émettant le signal amplifié, et à contrôler l'émission de lumière provenant de la couche active à une longueur d'onde ou dans une gamme de longueurs d'ondes distincte de celle du signal amplifié, et à commander le courant d'excitation fourni à la structure laser de façon à compenser au moins partiellement la diminution de la puissance de sortie contrôlée lors d'une augmentation de la puissance optique d'entrée.

10. Un procédé selon une quelconque des revendications précédentes, dans lequel le signal à amplifier a une puissance qui rentre dans la gamme comprise entre 1 µW et 5 mW inclus.

11. Un procédé selon une quelconque des revendications précédentes, dans lequel le signal à amplifier a une puissance qui rentre dans la gamme comprise entre 10 µW et 5 mW inclus.

12. Un ensemble d'amplification pour amplifier un signal optique qui comprend une source de signaux optiques, une structure de laser semiconducteur, des moyens pour appliquer le signal optique à amplifier à la couche active de la structure de laser semiconducteur, et des moyens pour faire passer un courant d'excitation au travers de la structure de laser semiconducteur, le signal amplifié étant émis à partir de la couche active en service, dans lequel la longueur d'onde du gain maximal de la structure de laser semiconducteur en correspondance avec ce courant d'excitation pour la limite inférieure de la puissance optique d'entrée λ_{max}, la plus grande des deux longueurs d'ondes de gain nul correspondant au courant d'excitation et pour la limite inférieure de la puissance optique d'entrée λ_{upper}, et la longueur d'onde du signal optique à amplifier λ sont liées par la relation suivante:

$$\lambda_{upper}>\lambda>\lambda_{max}.$$

13. Un ensemble selon la revendication 12, dans lequel:

$$(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})\geqslant 0{,}1.$$

14. Un ensemble selon la revendication 12, dans lequel:

$$(\lambda-\lambda_{max})/(\lambda_{upper}-\lambda_{max})\geqslant 0{,}2.$$

15. Un ensemble selon une quelconque des revendications 12 à 14, dans lequel λ_{max} rentre dans la gamme comprise entre 1,2 et 1,7 µm.

16. Un ensemble selon une quelconque des revendications 12 à 15, dans lequel le courant d'excitation est tel qu'il ne se produit pas d'effet laser.

17. Un ensemble selon une quelconque des revendications 12 à 15, dans lequel le courant d'excitation est tel qu'il se produit un effet laser et que la longueur d'onde du signal optique à amplifier est telle qu'un blocage d'injection du laser ne se produit pas.

18. Un ensemble d'amplification pour amplifier un signal optique, qui comprend une source de signaux optiques, une structure de laser semiconducteur, des moyens pour appliquer le signal optique à amplifier à la couche active de la structure de laser semiconducteur, et des moyens pour faire passer un courant d'excitation au travers de la structure de laser semiconducteur de telle sorte qu'il se produise un effet laser, la longueur d'onde du signal à amplifier étant telle qu'un blocage d'injection soit évité et que le signal amplifié soit émis à partir de la structure active.

19. Un ensemble selon une quelconque des revendications 12 à 18, dans lequel il est prévu un moyen pour contrôler la puissnace de sortie de la structure de laser semiconducteur à une longueur d'onde ou dans une gamme de longueurs d'ondes distincte de celle du signal amplifié et il est prévu une boucle de commande de réaction qui agit de façon à commander le courant d'excitation pour compenser au moins partiellement la diminution de la puissance de sortie contrôlée lors d'une augmentation de la puissance optique d'entrée.

20. Un ensemble d'amplification pour amplifier un signal optique, qui comprend une source de signaux optiques, une structure de laser semiconducteur, des moyens pour appliquer le signal optique à amplifier à la couche active de la structure de laser semiconducteur, et des moyens pour faire passer un courant d'excitation au travers de la structure de laser semiconducteur, le signal amplifié étant émis par la couche active en service, dans lequel il est prévu des moyens pour contrôler la puissance de sortie de la structure de laser semiconducteur à une longueur d'onde ou dans une gamme de longueurs d'ondes distincte de celle du signal amplifié et il est prévu une boucle de commande de réaction qui agit de façon à commander le courant d'excitation afin de compenser au moins partiellement la diminution de la puissance de sortie contrôlée lors d'une augmentation de la puissance optique d'entrée.

21. Un ensemble selon une quelconque des revendications 12 à 20, dans lequel le signal à amplifier a une puissance qui rentre dans la gamme comprise entre 1 µW et 5 mW inclus.

22. Un ensemble selon une quelconque des revendications 12 à 20, dans lequel le signal à amplifier a une puissance qui rentre dans la gamme comprise entre 10 µW et 5 mW.

23. Un ensemble selon une quelconque des revendications 12 à 20, dans lequel le signal à amplifier a une puissance qui rentre dans la gamme comprise entre 0,5 mW et 5 mW inclus.

24. Un ensemble selon une quelconque des revendications 12 à 23, dans lequel la structure de laser semiconducteur est du type Fabry-Perot.

Fig.1.

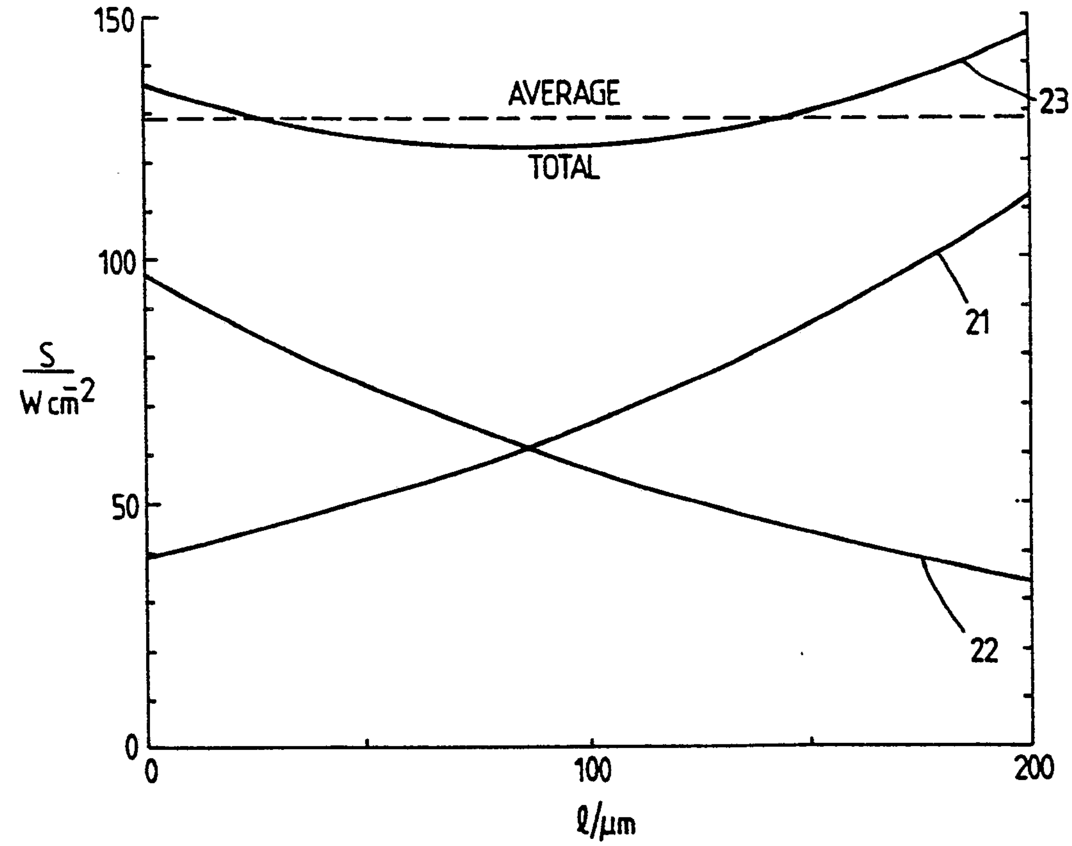

Fig. 2.

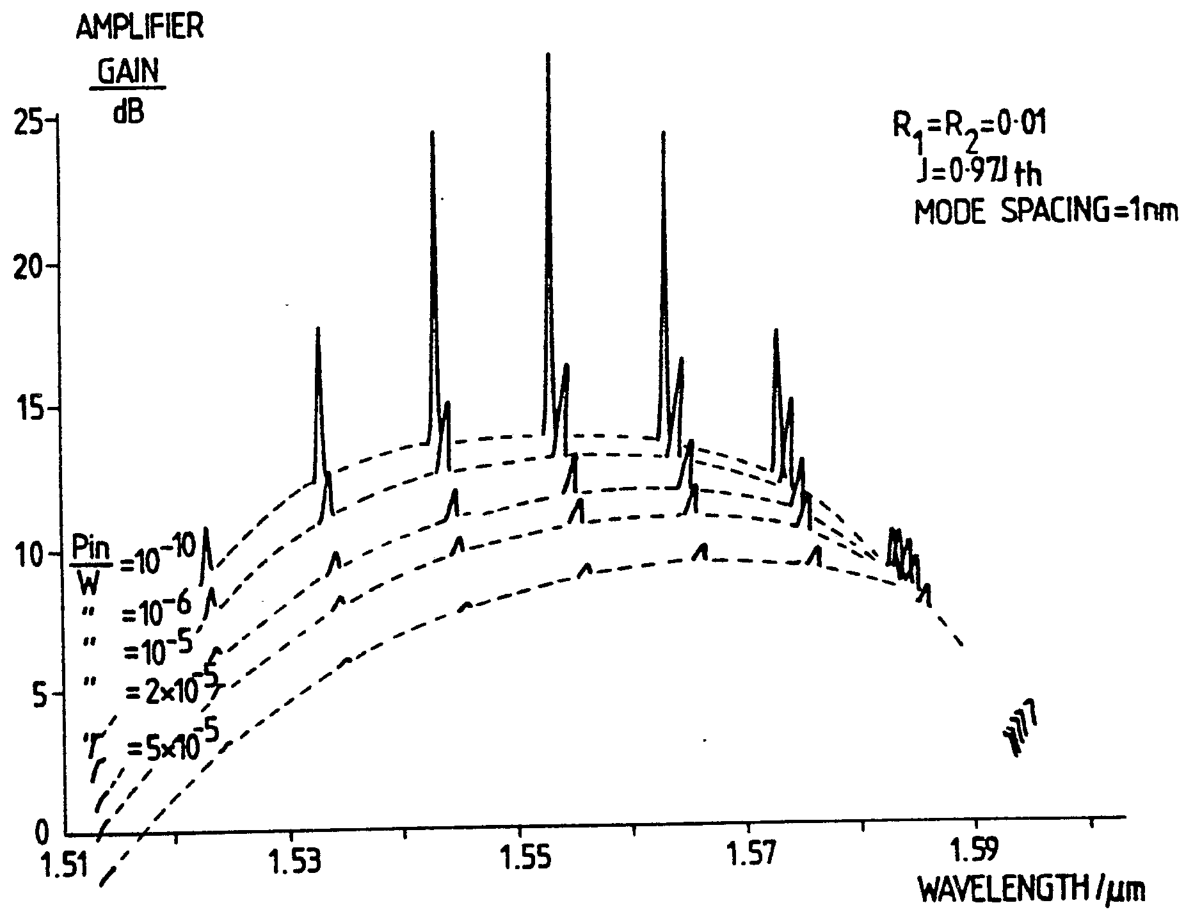
AMPLIFIER GAIN / dB
25
20
15
10
5
0
1.51
1.53
1.55
1.57
1.59
WAVELENGTH /μm
R1=R2=0·01
J=0·97J th
MODE SPACING=1nm
Pin/W =10−10
" =10−6
" =10−5
" =2×10−5
" =5×10−5

Fig.3.

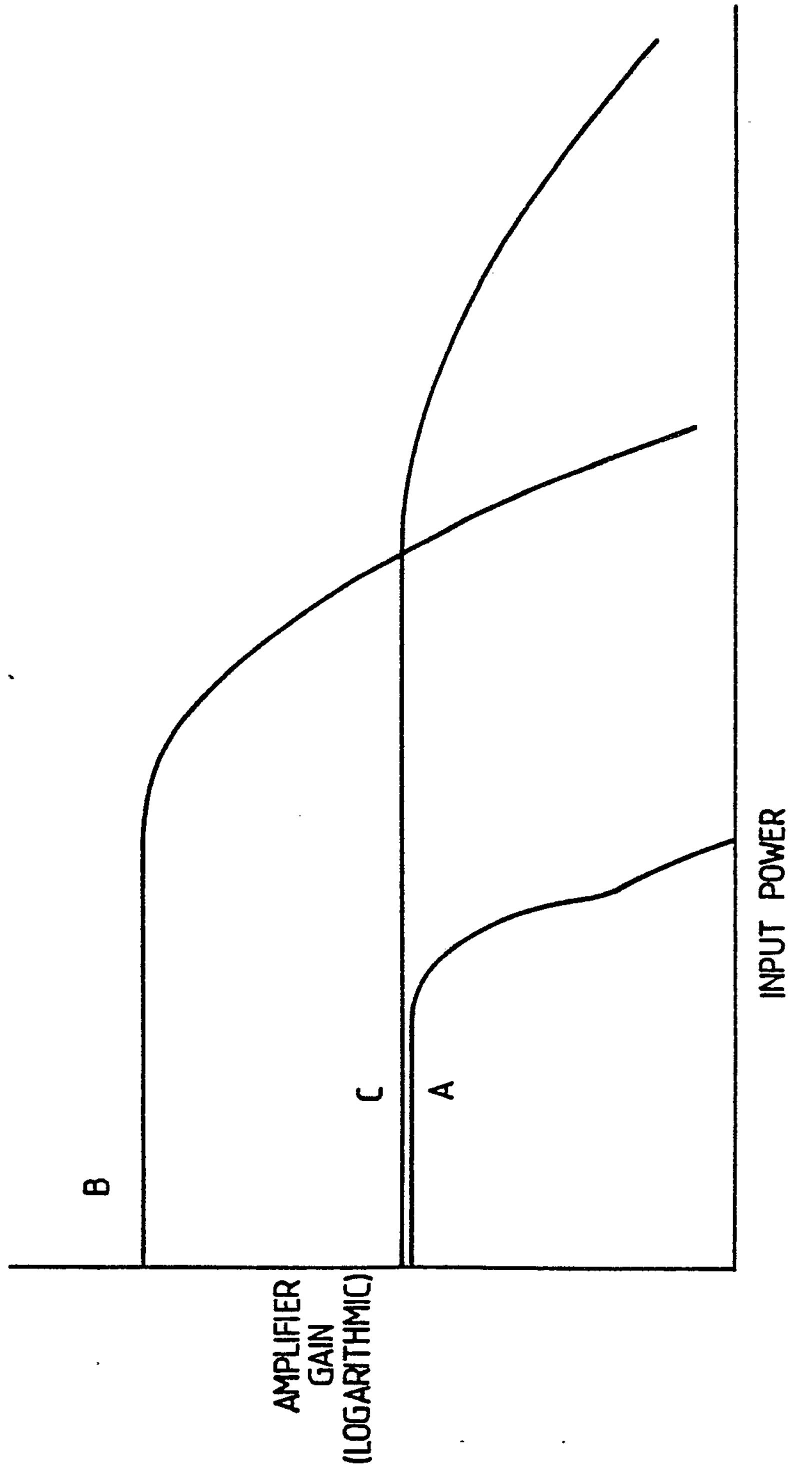

Fig. 4.